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Geochemical prospecting for copper in the northern part of Yuma County, Arizona

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GEOCHEMICAL PROSPECTING FOR COPPER IN THE NORTHERN PART OF YUMA COUNTY, ARIZONA

BY

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A

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ABSTRACT

Geochemical prospecting for copper has been carried out in two selected areas in the northern part of Yuma County, Arizona. These areas have a few old copper mines and some other zones of mineralization. The rocks of the area range in age from Precambrian to Quaternary and consist of complex gneiss, lava flows, schists, marble, sandstone, conglomerates and some intrusive dikes.

A cold-extractible field method was used to study the relation between the copper content of stream sediments in washes and the geology, mineralization, and topography of the areas. A few total copper tests were also carried out. Another purpose of the thesis was to find how well the cold-extractible method of geochemical prospecting would work in the environment of this region.

Because weathering has been mainly mechanical in nature, very little of the copper goes into solution and copper is mostly found in the fine fractions of the soil as particles of copper silicate and copper carbonate. The chemical results indicate that mineralization is associated with carbonate rocks. There is a strong relation between the copper dispersion and the rock types and structure of

the local area that each wash cuts through. The cold-extractible method is as good as the total copper method in finding and tracing the copper dispersion patterns; the simplicity and the low cost of the cold-extractible method make it the best test to use in this type of area. This method of prospecting should be useful in similar areas where mineralization is close to the surface.

Cold-extractible copper values for the area range from 0 ppm to 1200 ppm. Total copper values range from 250 ppm to 6400 ppm.

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I. INTRODUCTION

A. Purpose, Location, and Method of Investigation

The purpose of this thesis was to compare the copper content of stream sediments in the washes with the geology and mineralization of the area. A secondary purpose was to determine how well the cold-extractible method of geochemical prospecting would work in the environment found in this area.

Two separate regions near the western border of Arizona were selected for investigation. They occur in the northern part of Yuma County, Arizona (figure 1). These regions were chosen because several old mines are located in them. Region no. 1 is located about 16 miles east of Parker, Arizona and covers about 15 square miles. Region no. 2 is located about 8 miles northeast of Parker and covers about 30 square miles (plate I).

Samples were collected along washes of the two regions. They were taken from the washes at a depth of 1-2 feet. The samples were sieved to 60 mesh size particles and then were analyzed in the field for cold-extractible copper. Later laboratory analysis for total copper content of some samples was carried out at the Department of Geology and Geological Engineering, University of Missouri at Rolla.

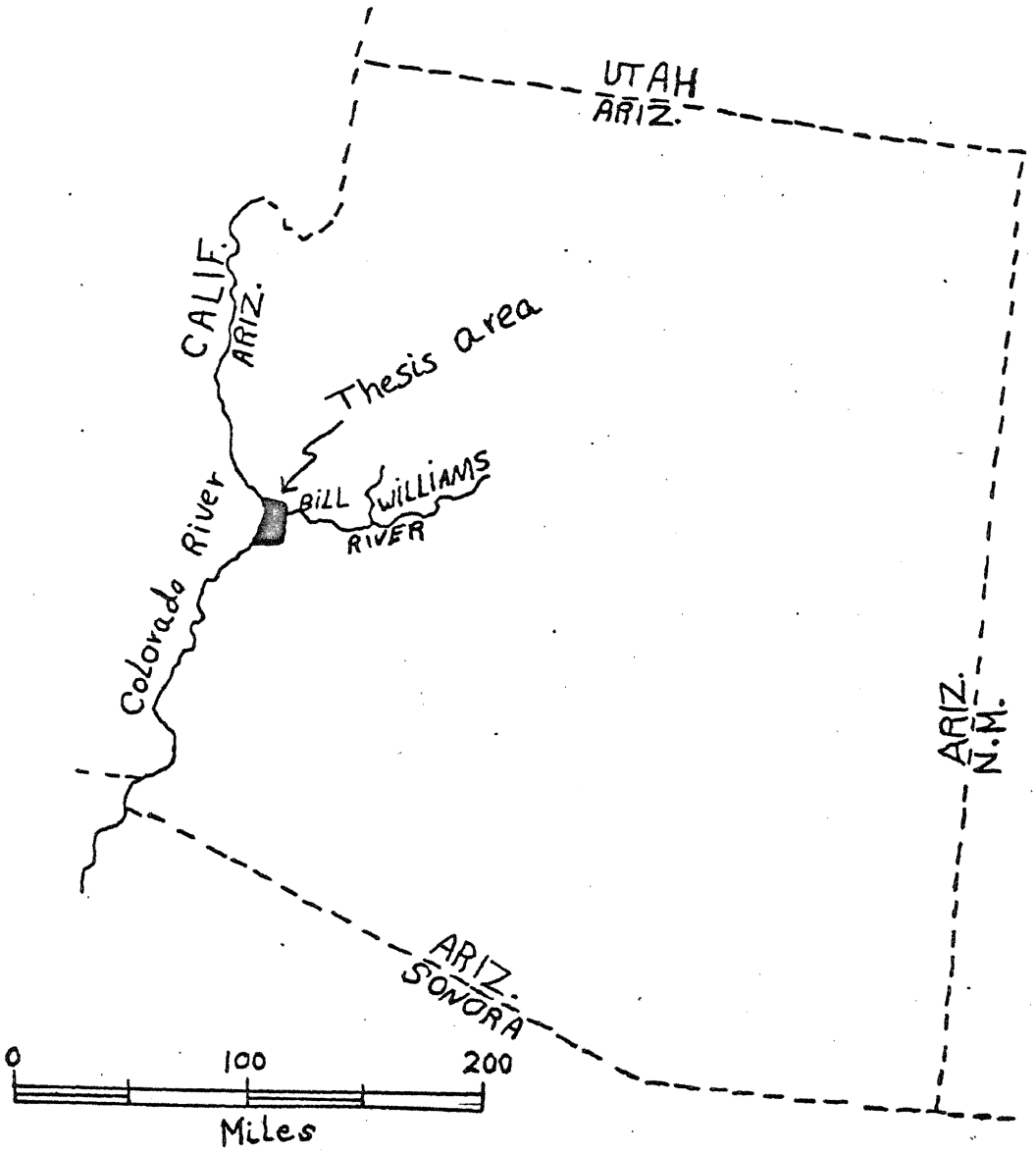


Figure 1. Boundary map of Arizona, showing location of thesis area.

B. Acknowledgments

The writer wishes to express his sincere thanks and appreciation to Dr. A. H. Brownlow for his field guidance, laboratory guidance, coordination and general supervision of this work. Dr. P. D. Proctor, Chairman of the Department of Geology and Geological Engineering, University of Missouri at Rolla, also provided field guidance and constructive ideas for the project. Mr. Vernon Pick provided financial support and encouragement.

II. TOPOGRAPHY, CLIMATE, AND GEOLOGY OF THE AREA

The following description of the area is mainly based on Howland Bancroft (1911), U. S. Geological Survey Bull. 451, pp. 7-126.

A. Topography

"The region investigated in this work shows typical desert topography. The area covered by mountain ranges is exceedingly small as compared with that of the valleys. Most of the ranges rise abruptly out of the desert and the intervening valleys, which slope with decreasing declivity down to the washes leading to the Colorado River and are filled with detrital materials resulting from the erosion of the mountains." In places the slope of the ranges are almost covered with this erosional debris. In some parts of the area erosion of lava flows has tended to make the topography somewhat rolling. "No deeply dissected stream valleys are present in the area except in the washes near the Bill Williams and Colorado rivers, where fairly steep, though short, precipitous canyons have been formed."

"The lowest elevation in the area occurs along the present stream bed of the Colorado River which is below 500 feet elevation. The highest peak attains an elevation

of over 5,500 feet. The average difference in height between the mountain tops and the valleys, however, is about 1,500 to 2,000 feet."

"In the main, the mountains are carved from old crystalline and metamorphic rocks, and the ridges and slopes are therefore fairly regular and lack the abrupt cliffs and terraces characteristic of ranges in which sedimentary rocks participate largely in the structure. In detail, however, the landscape bears the imprint of desert erosion of which small but steep scarps, jagged outcrops, and sharply cut remains are typical."

"Because of the almost total lack of vegetation in the region, little or no soil covers the mountains with the result that their contours and natural colors stand out with very marked prominence."

"The Colorado River and its tributaries drain the whole area. In the rainy season the various washes frequently have a large flow of water but this is only of temporary duration, seldom lasting over two days and frequently only several hours." The mean annual precipitation recorded at Parker during a period of 8 years is 4.27 inches.

B. Climate

Unlike the greater part of Arizona, which is over 3,000 feet in elevation, the portion covered in this work

is practically all under 2,000 feet. "This low elevation, combined with the southern latitude and the desert conditions which prevail throughout the region, tends to produce intense heat during the summer." The maximum temperature at Parker, Arizona in 1964 was 117° F in the month of July. The lowest temperature was 23° F in January. The mean annual temperature for the year 1964 was 72.3° F. Two inches of precipitation fell during the year 1964. "There is little or no snowfall in the area. The prevailing wind direction at Parker is southwest. Cacti of many different varieties form the most abundant vegetation in the area."

C. General Geologic Features

The rocks of the area have been divided by Bancroft (1911) into Precambrian, Mesozoic, Tertiary, and Quaternary.

The Precambrian rocks compose practically all hills and mountains of the area. They are capped by Tertiary lava flows. "Granites, gneisses, schists, quartzite, limestones, dolomite, and argillites constitute the Precambrian rocks." They are in many places cut by intrusive rocks of different kinds and ages. "Diabase, pegmatite, and aplite are the most common dike rocks, but other types are also present."

Most of the lava flows in the area have been assigned to the Tertiary system, several of the ranges are capped

by volcanic rocks and many prominent peaks in the area are composed entirely of igneous flows.

The broad valleys between mountain ranges, the river banks, and thick gravels north of the Bill Williams River all belong in the Quaternary system. Also some basalts are believed to be Quaternary.

D. Mineral Deposits

Bancroft (1911) suggested three periods of mineralization.

1. Precambrian

"Deposits considered as belonging to the Precambrian era are believed to have been formed at separate periods, and they represent several different types." Some hematite-copper deposits occur in limestone with intercalated amphibolite or tuffraceous material, at the Planet, Swansea, Pride, and Mineral Hill Mines. Copper deposits occur in shear zones in schist at the Wardwell & Osbourne and Carnation Mines. Gold-bearing quartz veins in granite and gneisses are considered the oldest type of deposits in the area.

2. Mesozoic

These deposits of copper and gold are associated with granite intrusions. Quartz monzonite porphyry has caused

some mineralization of this age. Numerous quartz veins found in the area are believed to have resulted from siliceous ore-bearing solutions accompanying the intrusions of granite.

3. Tertiary

"The Clara and Moro deposits near Swansea, occurring in tuff and sandstone, are probably of Tertiary age and may represent secondary deposition of material derived from the older underlying Precambrian rocks in which hematite-copper deposits are located."

The mineral deposits can be summarized as follows:

Gold deposits: Quartz veins and shear zones in granite, gneiss, schist, and metamorphosed sediments.

Copper deposits: Found in the Precambrian sedimentary series, as replacement deposits in limestone, in shear zones in amphibolite and chlorite schists, in shear zones and fissure veins in gneiss, in fissure veins in andesite, and as contact-metamorphic deposits. The copper occurs as malachite and azurite at the present surface. It originally formed as copper sulfides.

Iron deposits: Found as replacement deposits in limestone.

Lead deposits: Found as quartz veins which contain some galena.

Quicksilver deposits: Ore deposits containing cinnabar, in a shear zone, but through a sedimentary series of fine-grained quartz-mica schists.

E. Weathering

During the weathering of the copper deposits in the desert environment mechanical weathering is the main weathering process. The alluvium in desert arroyos that drain the area is a fairly well sorted mixture of fine sand and fine pebbles. At the head of the washes the area of recent alluvium is only a few feet across but then the washes get wider downstream. Downstream from mineralization the concentration of copper decreases due to dilution by mixing with other washes. Many of the churn-drill holes of the area penetrate rock relatively rich in copper, and drill cuttings, after being washed down the hillsides and incorporated in the alluvium, have modified the natural dispersion pattern.

III. SAMPLE COLLECTION, PREPARATION, AND ANALYSIS

A. Sample Collection

Stream sediment samples were collected during the summer of 1964 along washes approximately every 1000 feet and at a depth of 1-1.5 feet. A small steel shovel was used for sample collection. Samples were sieved immediately by the use of a 60 mesh sieve made from silk bolting cloth and plastic bottles. Paper bags were used for storing the fine fraction of the sieved samples.

A field testing kit made it possible to analyze samples immediately after they were collected, but most of the analysis work was carried out in the base camp.

B. Method of Analysis

A cold acid extraction of copper was used for sample analysis (Canney and Hawkins, 1958). This cold extraction method employs 2,2' biquinoline in isoamyl alcohol to determine the amount of copper after extraction with cold 6N hydrochloric acid for 30 seconds. The reagent is specific for copper and enjoys great stability under field conditions. A sensitivity of 1 ppm is obtained when a 0.2 gm sample is used. About two minutes are required for a sample determination and only simple portable equipment is required.

Reagents were prepared by the author in the laboratory of the Geology and Geological Engineering Department, University of Missouri at Rolla, at the beginning of the summer. Details on the preparation of reagents may be found in Canney and Hawkins (1958). The present writer took demineralized water with him in glass bottles, and stored it in the base camp. Also a simple distillating apparatus was taken in case of need for more demineralized water.

Minimum equipment required to perform the test at the sample site would be the following:

1. Volumetric scoop for sample measurement.
2. 2 oz glass bottle for 6N hydrochloric acid.
3. 4 oz polyethylene dispensing bottle for biquinoline.
4. 16 oz polyethylene dispensing bottle for buffer solution.
5. 25 ml graduated cylinder with a cap.
6. 5-7 test tubes for standard solutions.

There are many combinations of equipment that could be used at the sample site to dispense the reagents. The equipment listed above would hold sufficient reagents for about 40-50 determinations.

A series of copper standards for 0, 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 10, 15, 20, 25 and 30 micrograms of copper

were prepared. The standards were so stable that the author had to prepare liquid standards only twice during a period of 3 months. To prepare a standard, 1 ml of 6N hydrochloric acid was placed in each of a series of test tubes, then to each was added the required amount of copper to produce the series listed above. The regular procedure was then followed with the addition of buffer solution.

C. Procedure

Place 0.2 gm of the sample in a 25 ml graduate cylinder, add about 1 ml of cold 6N hydrochloric acid, and slosh the sample in the acid for about 30 seconds. Add 10 ml of buffer solution, 2 ml of 2,2' biquinoline solution, cap the cylinder and shake vigorously for about 30 seconds. Allow to stand for a few seconds until the isoamyl alcohol layer separates sufficiently, then compare with the copper standards. A standard should be run at the start of each day's work as a check on the reagents and liquid standards to insure comparable results from day to day.

A pyrosulfate-fusion technique (Fulton, 1950) was used to determine the total copper present in the soil. In general the technique is to place 0.1 gm sample in a pyrex test tube with 0.5 gm of potassium pyrosulfate flux and fuse the mixture for about 7 minutes after the flux melts. When

the tube is cool add 3 ml of (1:1) HCl and place it in a hot water bath until the melt has disintegrated. Remove the tube from the water bath and dilute the sample solution to 10 ml with demineralized water. Shake the tube vigorously to mix the sample solution, finally take 1 ml from this solution to test for Cu, using 2,2' biquinoline.

IV. DISCUSSION OF RESULTS

A. Area No. 1

The three main groups of rock are:

1. gneissic complex
2. schist
3. marble and dolomitie marble (Fernandez, 1965; plate II)

The gneiss is believed to be Precambrian and the other units were mapped by Fernandez to be conformable. There is a regular mineralogical similarity between the schist and gneiss. Quartz and feldspar are predominate with minor biotite, chlorite, and epidote. In most cases there is a passing gradation between the gneiss and schist, not only mineralogically but structurally. The marble occurs conformably on top of the two rock units described above. Some thin layers of marble were found by Fernandez to form regular intercalations with the gneiss and schist.

The samples for this work were collected along washes nos. 1, 2, 3, and 4 of area no. 1 (see plate II). Plate II shows that wash no. 1 cuts through the gneiss, then through the alluvium. Very little carbonate rock occurs in this region. In spite of the mineralized zone between samples 80 and 81 we see that the copper content in the

soil is very low. This may be because the soil in this part of the area is less carbonaceous than that of washes 2 and 3. Wash no. 2 first cuts through the gneiss and some carbonate rocks, then through the alluvium. The cold-extractible copper in this wash is slightly higher than that of wash no. 1, with an average for the wash of about 3.5 ppm. The highest values for copper were found in wash no. 3. This wash cuts through the gneiss first, then through a large mass of carbonate rock. Samples 93, 94, and 95 contain 20, 35, and 20 ppm cold-extractible copper respectively. The source of the copper is the mineralized zone associated with the Pride Mine. Copper from this zone was not found in wash no. 4. This indicates that the copper is mainly associated with the carbonate rock.

The cold-extractible copper to total copper ratio is about 0.1 in this area. This is typical of a syngenetic dispersion pattern (Hawkes and Webb, 1962). The copper is dispersed as a result of mechanical weathering with very little chemical weathering. The mechanically dispersed copper probably occurs as very fine grains of copper carbonate minerals. Analysis shows that the copper content of the fine fraction of a sample is generally higher than that of the coarser fraction. This may be because malachite and

azurite easily break down by abrasion during transportation. Also using the fine fraction for the test gives a more representative sample of the soil by increasing the number of the fragments in the sample. Copper is not dispersed far from its source. In most cases it can be traced for 1 to 2 miles from the source.

There is a brecciated zone exposed in the northeast corner of the area as an indication of a fault zone. This zone could be traced to the south, southeast as shown by the high copper content in samples 101, 97, 76, 77, and 78. These samples have high values although there has not been any mining activity in that zone. Where wash no. 1 leaves this zone at the site of sample 79, the soil copper content falls to zero. It increases again at the site of sample 80 near the New Standard Mine where another fault zone occurs.

The above relations indicate that high copper values and mineralization are associated with the carbonate rocks and faulting. These high values can be detected in washes which transect such rocks and zones. Thus from these results we see that there is a clear relation between the geology of the area and the copper dispersion. This relationship is shown better by the cold-extractible copper test than it is by the total copper test. This may be partly because the ore is mainly carbonate and the carbonate

particles in the soil vary in size. In the case of the fault zone, as a result of the shear action, more of the materials will be mechanically broken down, making copper more extractible than in an area that is not in a fault zone. In the total copper method variations due to different particle size will not be shown. Also, the copper carbonate associated with the carbonate rocks has probably formed as a result of ground water action and this copper is thus easily extracted by the cold-extractible method, while copper silicates formed in other areas would only be affected by the hot test.

B. Area No. 2

The environment, the sampling, and the dispersion are generally the same in this area as in area no. 1. However, in this area the structure is more complicated, and the rock types are more varied (Zambrano, 1965). Area no. 2 consists of unmetamorphosed lava flows, sediments (sandstone and conglomerates), and some intrusive dikes in addition to gneiss, marble and schist. These rocks are Mesozoic and Tertiary in age (plate III).

The zero values of wash no. 4, which cuts through the lava flows, indicate that they are distant from mineralization.

The zero values of wash no. 6 give the same indication, but the wash in this case cuts through a complex gneiss.

Washes nos. 1, 2, 3, 5, and 7 cut through the other types of rocks present, the sediments and the carbonate. The amount of cold-extractible copper increases in all of these washes toward the mineralized zones. The mineralized zones in this area are large compared to those of area 1. As a result the soil has higher values of copper. Anomalies extend down along the washes 2-3 miles from the source.

Following wash no. 1 (plate III, figure 2) from the site of sample 129 to the site of sample 147, we see that the copper content varies in a clear pattern as we move from one rock type to another. Thus the test results vary with the geology and structure of the region that the washes cut through. Sample 129 has zero copper content. Suddenly the value increases to 87.5 ppm at the site of sample 130, near which a malachite-azurite vein is exposed on the side of the hill. The maximum value is found at the site of sample 131 (100 ppm). Then the anomaly dies out down the wash until it becomes zero at the site of sample 140. The copper content increases when the wash again cuts through a carbonate rock, where there has been some mining activity. It reaches its maximum at the site of sample 141 (125 ppm). Then it decreases further down the wash. A high value is found at the site of sample 143 (90 ppm) where there is a fault zone

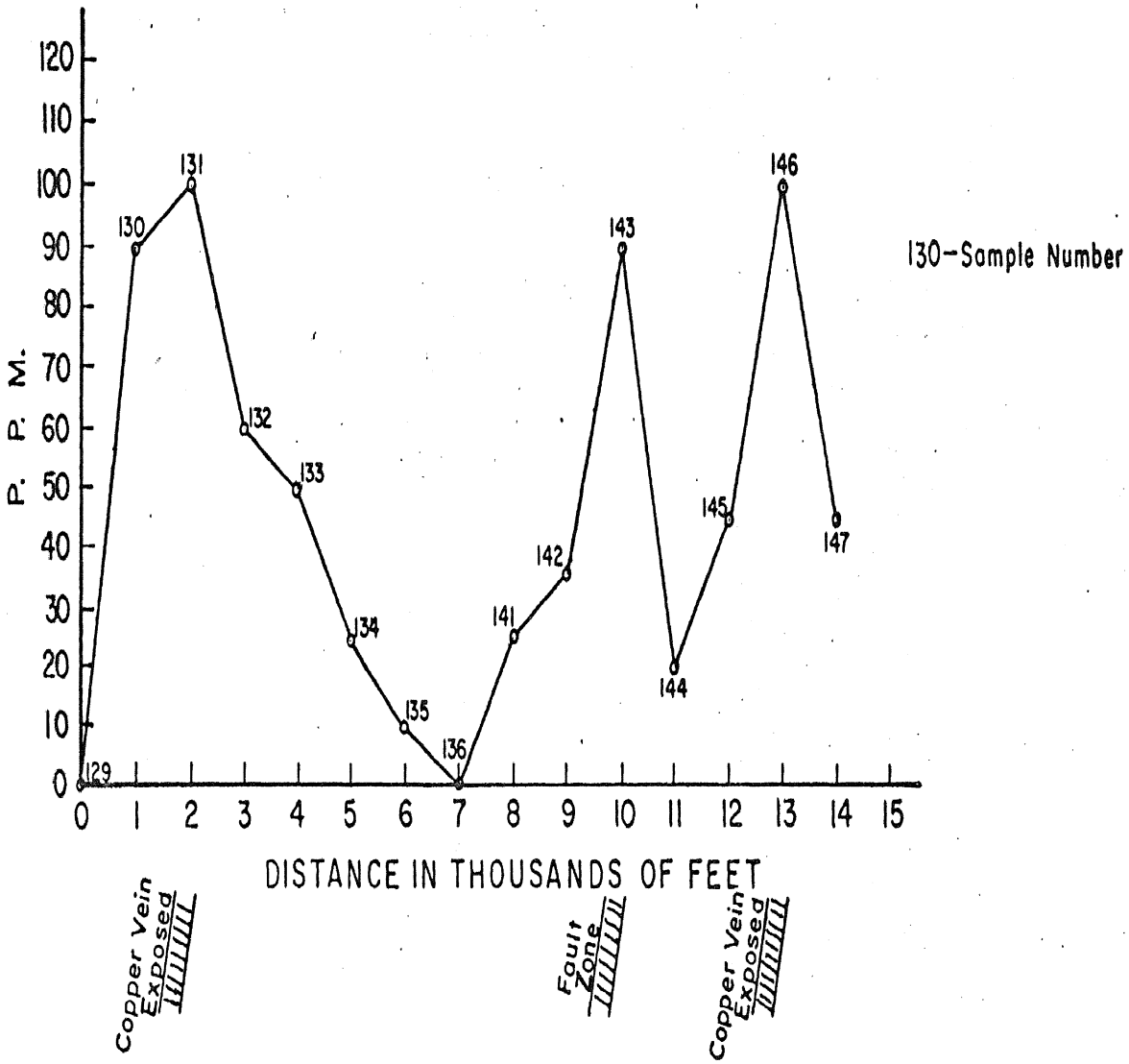


Figure 2. Graph showing relation of cold-extractible copper content in the soil to rock types and structure, wash no. 1, area no. 2.

with some copper mineralization. There has been no mining activity around the site or near it. It is likely that this fault zone is a continuation of the mineralized zone of the Sue Mine. Leaving the site of sample 143, the value goes down to 20 ppm, then up again at the site of sample 146 (100 ppm), due to the presence of a copper carbonate vein which has been exposed on a high cliff on the north side of the wash. At the site of sample 147 the copper content decreases to 45 ppm. This wash is an excellent example for showing how good the method of investigation used is in determining the relation between the copper dispersion and the geology and the structure of the area that the wash cuts through. Wash no. 2 is similar to no. 1 (Fig. 3).

Washes nos. 3 and 4 show the same relations as nos. 1 and 2 as far as the copper dispersion is concerned. One more phenomenon is well defined in these two washes. This phenomenon is known as dilution. When two washes come together to form one wash, and one of the washes contains high values of copper and the other does not, then dilution of the copper values occurs. A good example is wash no. 3b, which originated in the lava flows and has no copper content, and wash no. 3a which originated in carbonate rock in which some mineralization is present. Sample site 184 has zero

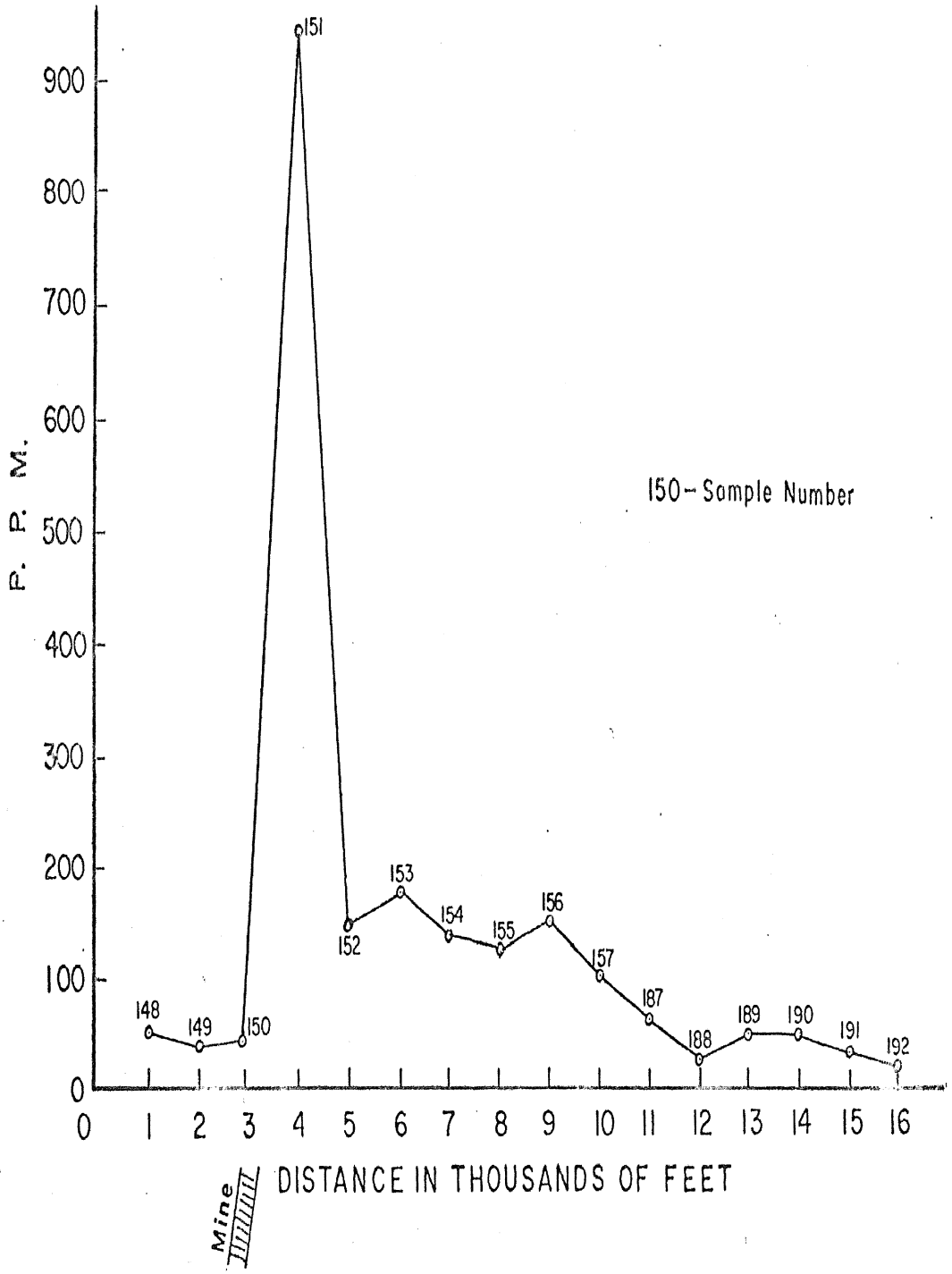


Figure 3. Graph showing relation of cold-extractible copper content of the soil to rock types and structure, wash no. 2, area no. 2.

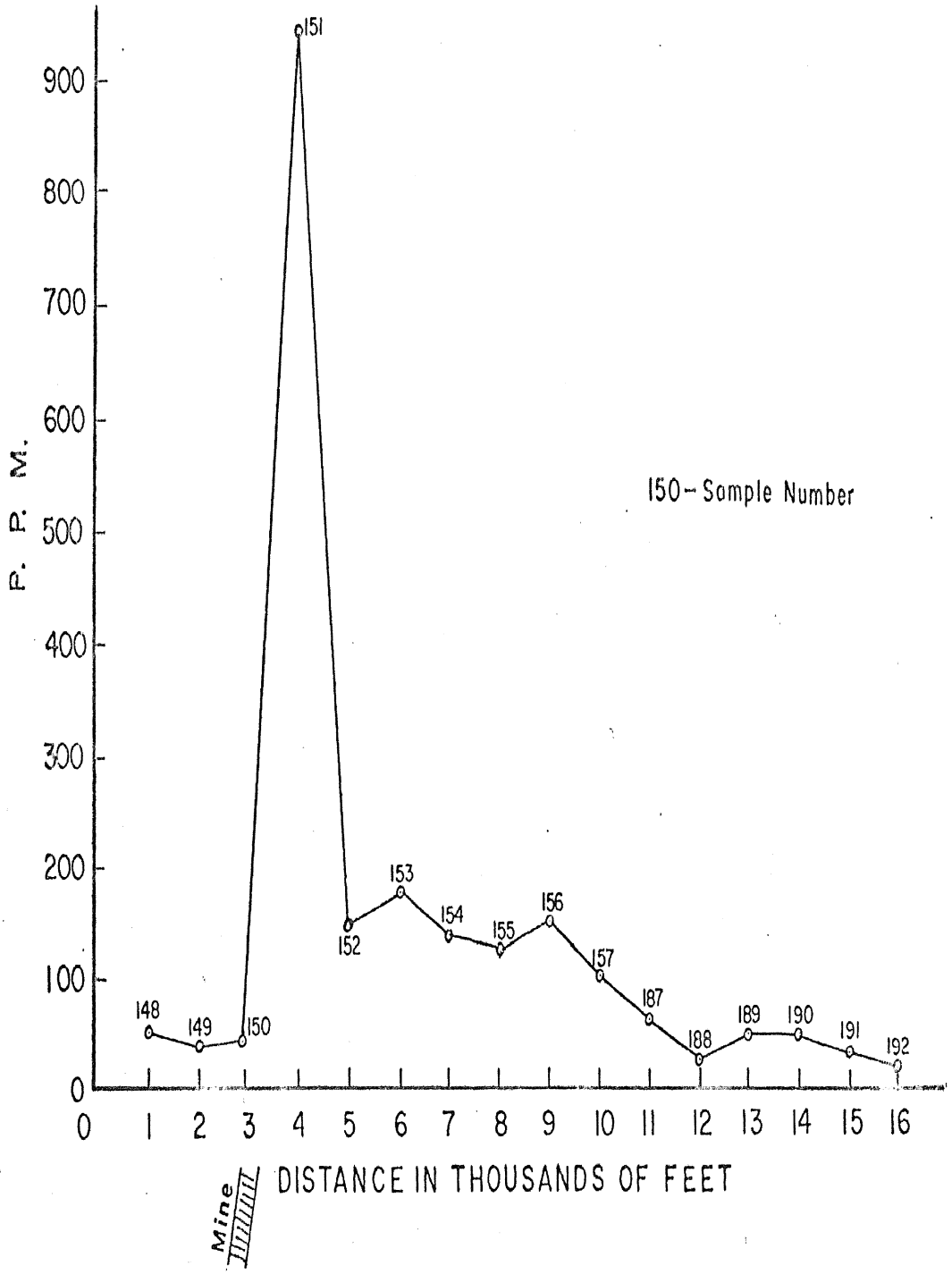


Figure 3. Graph showing relation of cold-extractible copper content of the soil to rock types and structure, wash no. 2, area no. 2.

ppm and sample site 158 has 25 ppm. After the two washes join together to form one wash the copper content at sample site 186 is 10 ppm. This is higher than that of wash 3b and lower than that of wash 3a.

The same thing happens when wash no. 3 joins with wash no. 2 (figure 4). Sample no. 187 has 60 ppm and sample 186 has 10 ppm Cu, while sample 188 has 25 ppm, which is lower than 187 and higher than 186. The value then increases again at the site of sample 189 (50 ppm) to give the regular dispersion pattern. Dilution occurs also when wash no. 5a (plate III) joins wash no. 5b to form wash no. 5. Samples 174, 172, and 173 have a copper content of 200 ppm, 0 ppm, and 65 ppm respectively.

Wash no. 7 is an excellent example for showing the relation between the copper dispersion in the down-wash direction and the source of the mineralization (figure 5). The cold-extractible copper content increases up the wash until it reaches a maximum at the site of sample 208 (1200 ppm). Then it drops to 10 ppm at the site of sample 209. This sudden change indicates a source of mineralization near the site of sample 209. Farther up the wash at the site of sample 210 the anomaly has died out completely as shown by the zero ppm copper content.

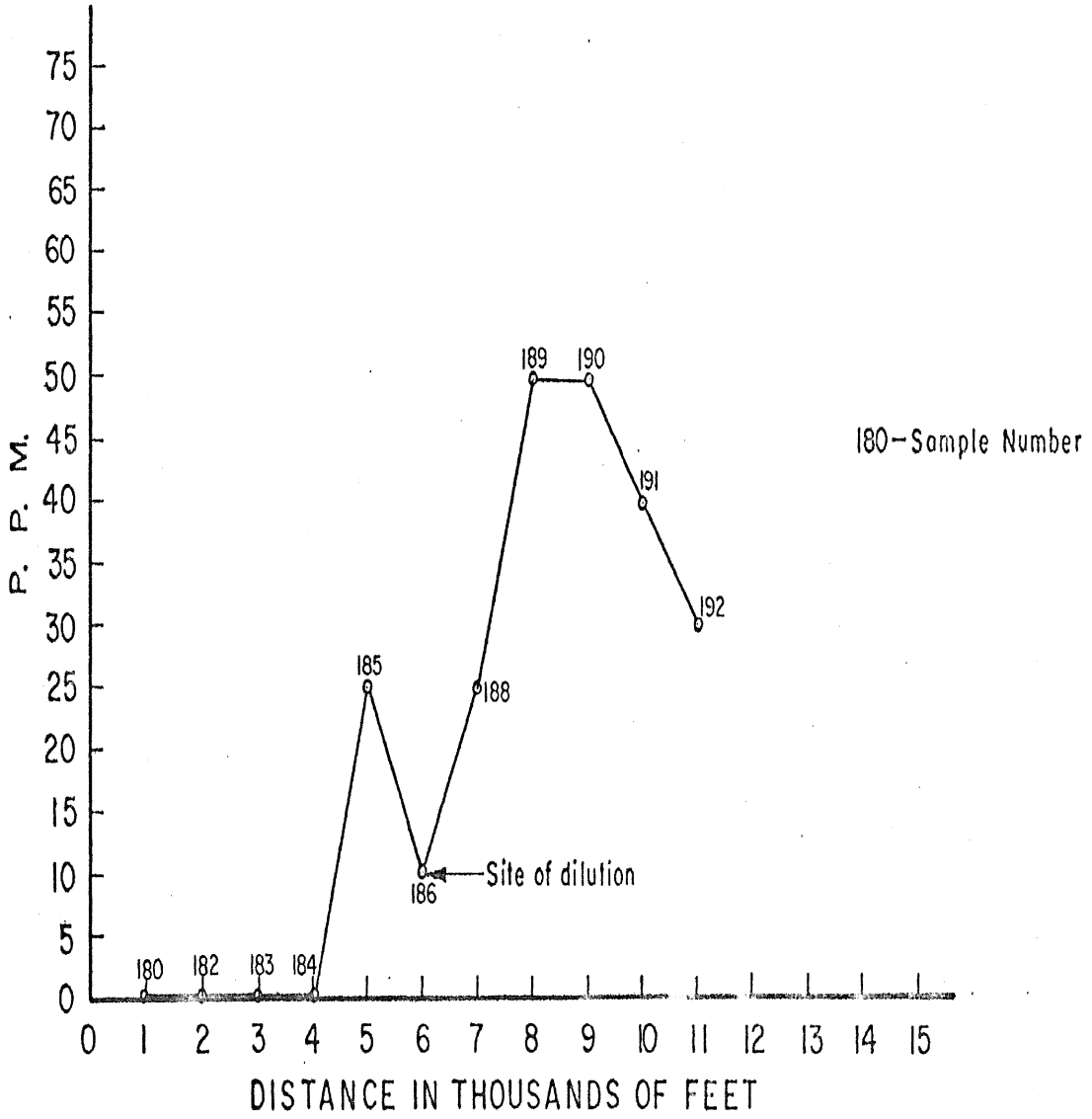


Figure 4. Example of dilution, wash no. 3, area no. 2.

By reviewing the results from this area we can come to the same conclusions found for area no. 1, that the copper mineralization is mainly associated with carbonate rocks and copper dispersion is related to the rock types that each wash cuts through. Thus a rough geologic map could be drawn by using the dispersion pattern of the copper on the basis that the mineralization is mainly associated with carbonate rocks and the other rocks have nothing to do with the mineralization. In some cases the mineralization is related to faulting and this may be shown by the copper dispersion also.

By comparing the values of cold-extractible copper with total copper (figures 5, 6, and 7), we find that they give similar results, all the anomalous values being picked up by the cold test as well as by the total copper test. Since it is more convenient, faster, and cheaper to use the cold test for geochemical prospecting, this should be used in areas similar to those discussed here.

C. Comparison with Previous Work

Lovering, Huff, and Almond (1950) studied the dispersion of copper from the San Manuel copper deposits, Pinal County, Arizona. They tested soil, alluvium, ground water, and plants. The test method used for soil was a reflux of the

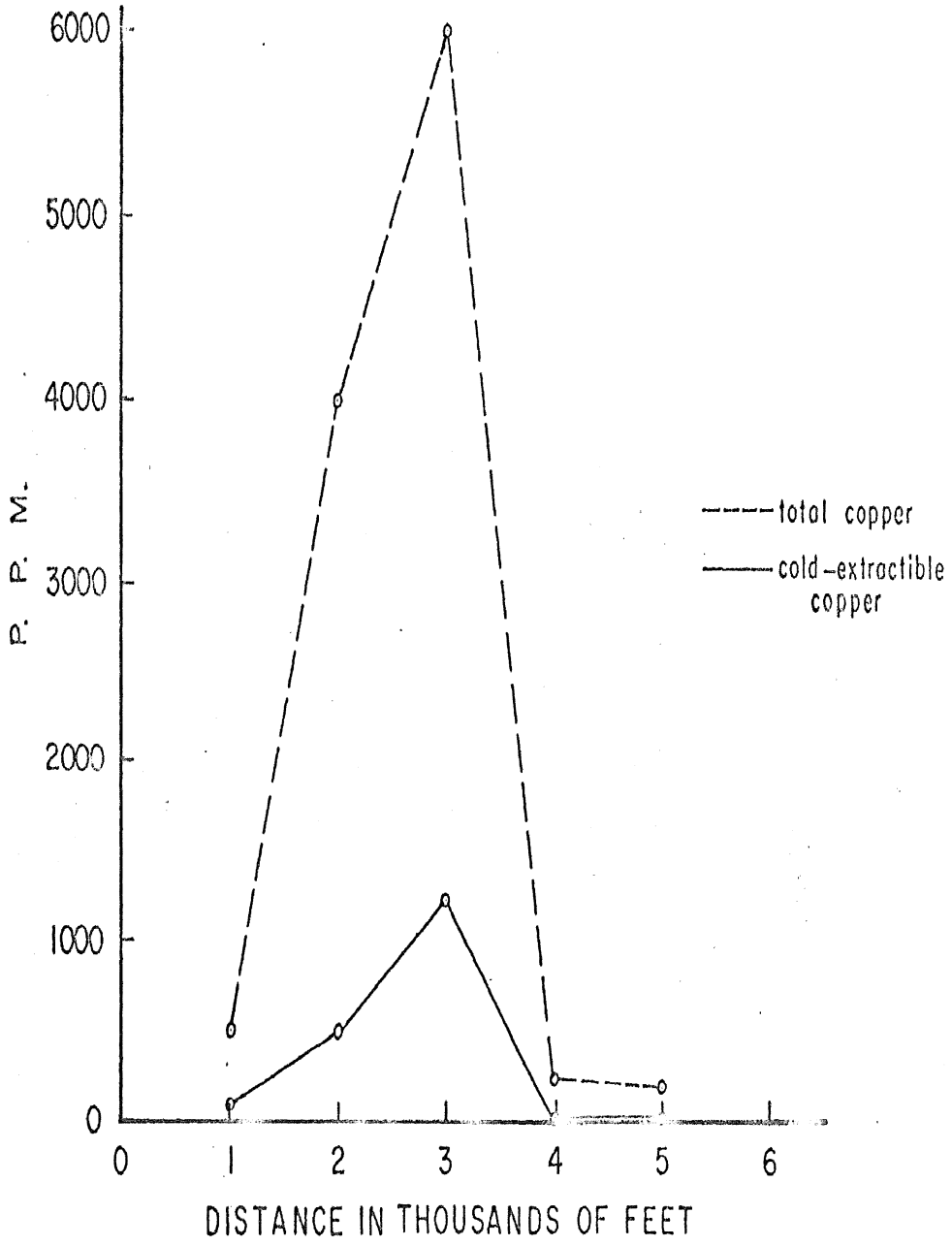


Figure 5. Comparison of copper content as determined by cold-extractible method and by total copper method, wash no. 7, area no. 2.

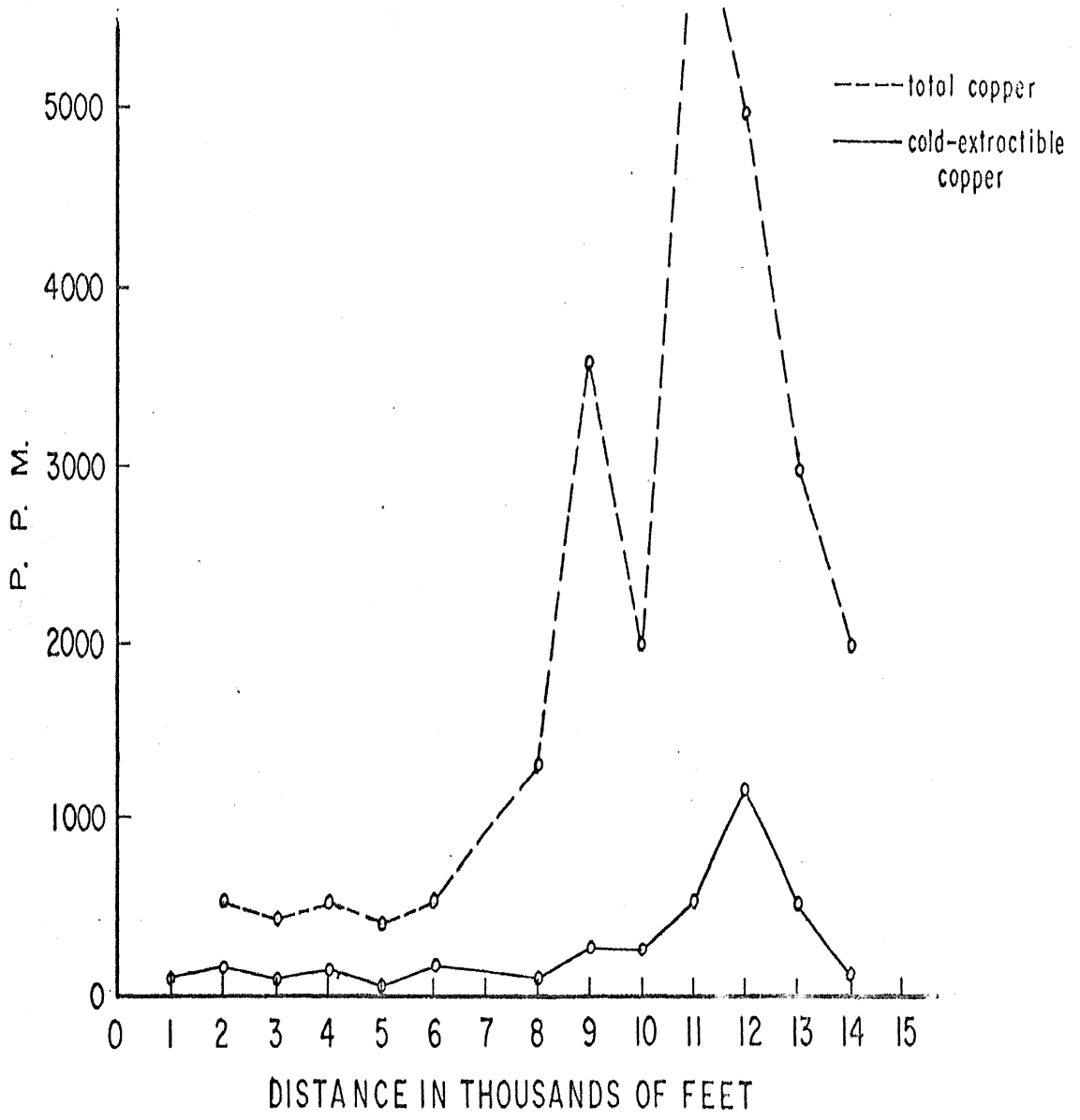


Figure 6. Comparison of copper content as determined by cold-extractible method and by total copper method, wash no. 5, area no. 2.

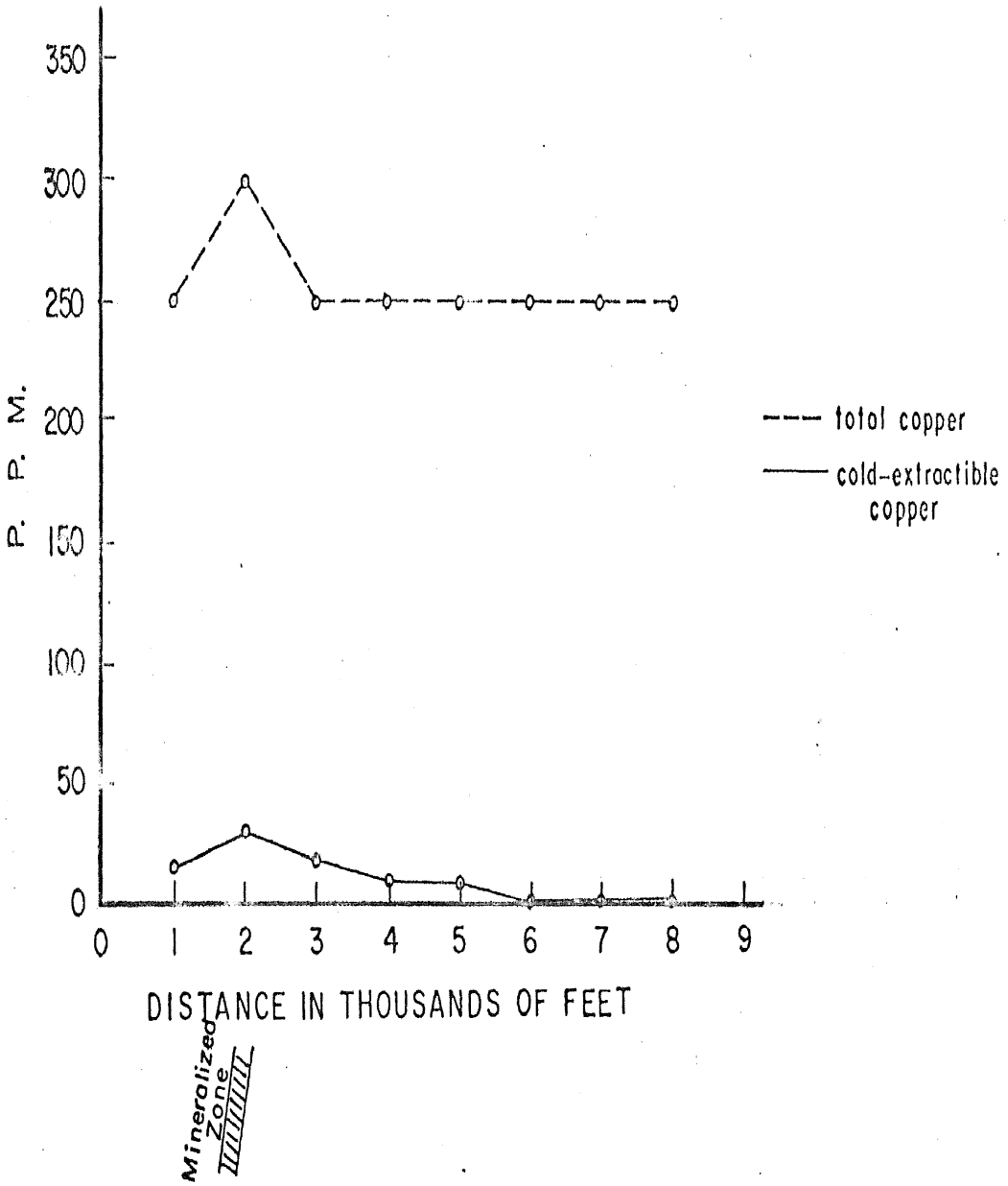


Figure 7. Comparison of copper content as determined by cold-extractible method and by total copper method, wash no. 3, area no. 1.

sample with 0.1 N hydrochloric acid, with copper then extracted by ammonium citrate and detected by dithizone. They concluded that the dispersion of copper in this area is purely mechanical. The copper-rich soil migrates as a thin layer down the hillside until it reaches one of the desert washes. During floods the copper-rich material is incorporated in the alluvium and swept downstream. They believe that mechanical abrasion tends slightly to concentrate the copper in the finer sizes downstream. The net change, however, is a decrease in copper content caused by dilution with copper-poor materials from tributary arroyos. The distance that the copper can be traced depends upon the copper concentration in the neighboring rock as well as upon the concentration of copper in the oxidized ore and its area of outcrop. They also found that geochemical studies of copper dispersion in the basement complex, the Gila Conglomerate, ground water, and plants, promise little as an aid in prospecting for ore bodies that come to the surface. The most favorable approach appeared to be studies of the copper dispersion in soil and alluvium. Samples of alluvium more than one mile downstream from the ore outcrop showed a significant anomaly. The dispersion could be traced most easily by sampling only the fine fractions of the samples.

The conclusions of these investigators are almost the same as those of the author. Because the method which they used involves the reflux of the sample for 30 minutes and the use of dithizone for detection, there are many sources of errors in this method. The first step of analysis is time consuming. In the second there is a possibility of making errors in detection of copper present, using dithizone, because a slight change in the pH will make it possible for the dithizone to react with either zinc or lead, if they are present in the sample. They are present in the San Manuel area and give the same color when they react with dithizone as the copper does. Thus it would be possible to measure lead and zinc as well as copper and to assume it is all copper. Buffer solution was not used by these investigators to control the pH. In the method the author used all these possible errors were eliminated by using buffer for controlling the pH and 2,2' biquinoline for detection of the copper. 2,2' biquinoline is a specific reagent for copper.

V. SUMMARY AND CONCLUSIONS

1. The mineralization in both areas is associated mainly with carbonate rock; a second factor is faulting. The other rocks have nothing to do with the mineralization unless faulting occurs in them.
2. There is a definite relationship between the copper dispersion and the rock types and structure of the region that each wash cuts through. Fault zones, unexposed brecciated zones, and unexposed mineralized zones can be traced or detected by testing the soil or alluvium on the surface.
3. A very rough geologic map could be drawn from the variation of the copper dispersion pattern.
4. Very little of the copper goes into solution. The main process of weathering is mechanical weathering. The fine-grained particles of copper minerals move down the side of the hills toward the washes and are incorporated there with the alluvium.
5. Dilution occurs when a copper-poor wash joins a copper-rich wash.
6. Copper is found mainly in the fine fractions of the soil or alluvium. Thus it is better to test the fine fraction in order to determine copper dispersion.

7. The reagents used are very stable under field conditions.

8. The cold-extractible method is as good as the total copper method in finding and tracing the copper dispersion patterns. The simplicity and low cost of the cold-extractible method make it the best test to use in this type of area. Also, results can be obtained immediately after collection of the sample.

9. This method of prospecting should be useful in similar areas where mineralization is close to the surface.

10. Larger amounts of mineralization are indicated by higher copper values in the associated anomalies.

11. The cold-extractible copper in this area varies from 0 to 1200. The total copper content varies from 250 to 6400.

APPENDIX A

BASIC PRINCIPLES

The following material is taken from Hawkes and Webb (1962).

1. Definitions

Geochemical prospecting is defined as any method of mineral exploration based on systematic measurement of one or more chemical properties of a naturally occurring material as rock, soil, gossan, glacial debris, vegetation, stream sediments or water in order to find an abnormal chemical pattern or geochemical anomaly related to mineralization.

Geochemical anomaly refers to an abnormal chemical pattern or when you have a relatively high concentration of specific elements related to the surrounding. Anomalies that are related to ore bodies and that can be used as a guide in exploration are called significant anomalies. Anomalies that are unrelated to ore body are called non-significant anomalies (figure 8).

Background refers to the normal abundance of an element in barren earth materials. This varies considerably according to the nature of the earth material in which it occurs. It is effected also by the nature of the environment in that area.

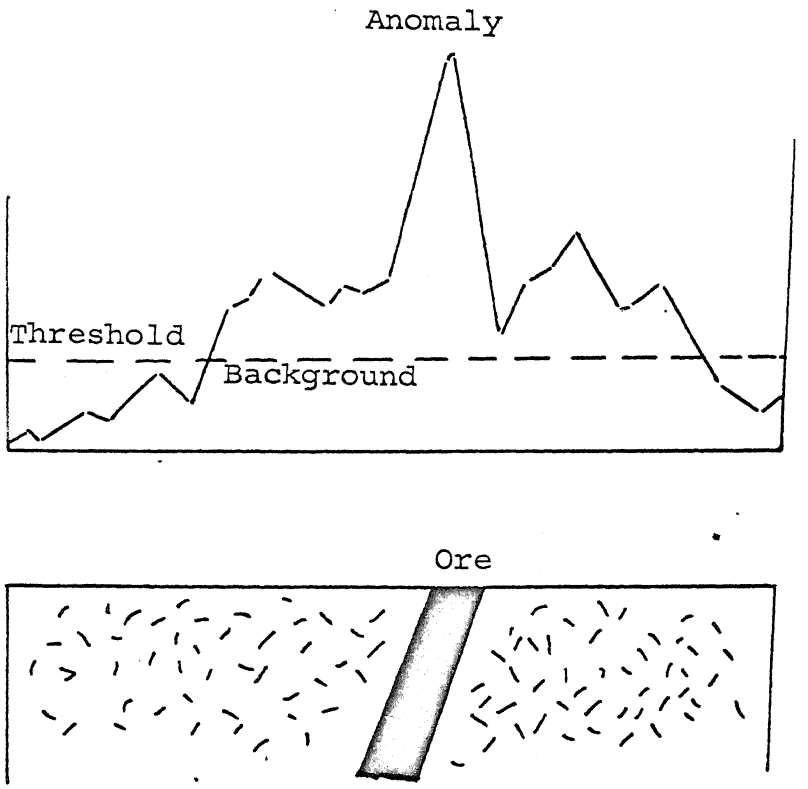


Figure 8. Diagram showing relation between anomaly, threshold, and background.

Threshold refers to the upper limit of the normal background fluctuation. Any concentration over the treshold value is referred to as a geochemical anomaly (figure 8).

Contrast is defined as the ratio between the anomaly value and the background. This ratio is controlled by the following factors:

a. The primary contrast between ore and country rocks.

b. The relative mobility of elements in the dispersion environment.

c. Dilution with barren materials.

Mobility is defined as how easily an element can move in a given environment. This is controlled by:

a. pH-Eh of the environment.

b. Solubility of the element.

c. Amount of coprecipitation of materials.

d. Amount of adsorption of material.

e. Effect of organic materials.

Dispersion is defined as the distribution of elements by natural processes. On the basis of the environment of dispersion, it can be divided into two parts:

a. Primary dispersion: occurs in association with the primary geochemical environment of igneous and metamorphic rock. It is characterized by:

(1) Deep-seated location.

(2) High pressure and temperature.

(3) Low free oxygen content.

b. Secondary dispersion occurs in the secondary geochemical environment of weathering and sedimentary rocks formation. It is characterized by:

(1) Weathering, erosion, and sedimentation at the surface of the earth.

(2) Low temperature and pressure.

(3) Free oxygen, water and CO_2.

Syngenetic dispersion patterns are defined as the distribution patterns resulting from materials formed at the same time as the surrounding material. Epigenetic dispersion patterns are those formed by material introduced in some way into a pre-existing matrix.

2. Geochemical Survey

The first step in the study of an area is to conduct an orientation survey. Such a survey normally consists of a series of preliminary experiments aimed at determining the existence and characteristics of anomalies associated with mineralization. This information may then be used in selecting adequate prospecting techniques and in determining the factors and criteria that have a bearing on interpretation of the geochemical data.

Although the orientation study will provide the necessary technical information upon which to base operational procedures, the final choice of methods to be used must also take into account other factors, such as cost of operation, availability of personnel, and the market value of the expected ore discoveries.

If possible, these preliminary experiments should be undertaken in the vicinity of a known deposit that has not been disturbed or contaminated by human activity, so that the natural geochemical patterns can be observed. It is important, however, that orientation should be conducted in areas where the geological and geomorphological characteristics are representative of those likely to be encountered during prospecting.

Determination of the distribution of metal values in unmineralized terrains is of equal importance. Background studies must be carried out well away from the possible influence of known mineralization. They should also cover the full range of environmental conditions that exist in the exploration area.

For soil and stream sediment surveys the nature of the overburden, whether of residual, glacial, alluvial or wind-born origin, is the first question that must be

answered by the orientation survey. Sometimes it is surprisingly difficult to discriminate between residual and transported soil. The safest method, therefore, is to make critical and careful examination of complete sections of the overburden at the start of every new field survey. If road-cut exposures are not available, the soil profile should be examined by pitting or augering.

The orientation study of a new area should also include appropriate sampling to determine the extent of possible contamination arising from human activity, as fertilizers, trash, road metaling, industrial installations, smelters, mine dumps, etc.

The actual mechanics involved in an operational survey is a matter of determining the cheapest and most efficient means of gathering the required data.

The sampling pattern is determined primarily by the size and shape of the target. A sampling grid should be laid out in such a way that at least four samples will fall within the limits of the smallest expected anomaly. Samples should be taken from one soil horizon. Location of sample sites or sample traverses need only be accurate enough to enable any anomalous sites to be revisited in the field. Samples collected may be located directly on aerial photographs or topographic maps if available.

The choice of analytical procedures will depend to a large extent on the form in which the element is held in the overburden. Determination of both the total and readily extractible metal (cold test method) is helpful in differentiating between syngenetic and epigenetic anomalies.

The choice of the element to be determined is generally based on considerations of relative mobility, together with suitability of available analytical techniques. The precision of the analytical procedure should be high enough that the analytical errors will be small compared with the natural range of background fluctuation.

Two different kinds of maps are commonly prepared in the course of recording and interpreting the data of geochemical prospecting surveys. One of these, the data map, is simply a vehicle for the geochemical data. The other is an interpretation map that embodies a greater or less degree of graphical generalization of the data.

In general terms the interpretation of geochemical soil data involves four main problems:

a. Estimation of background and threshold values (figure 8).

b. Distinguishing between significant and nonsignificant anomalies.

c. Distinguishing between lateral and superjacent anomalies (figure 9).

d. Appraising the significance of anomalies in terms of possible ore, with view to selecting those that merit further investigation.

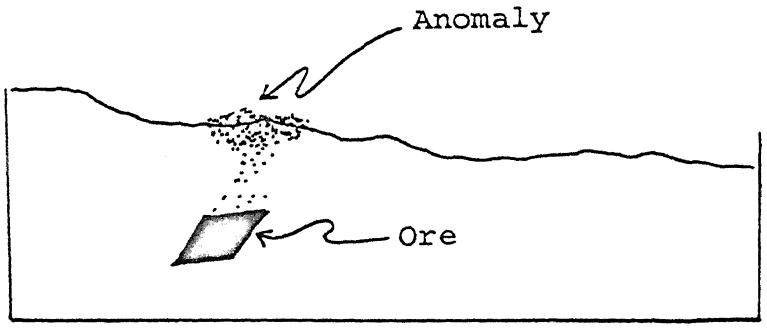
The principal types of anomalies that are not related to mineral deposits include those resulting from:

a. Barren rock types characterized by a relatively high background metal content.

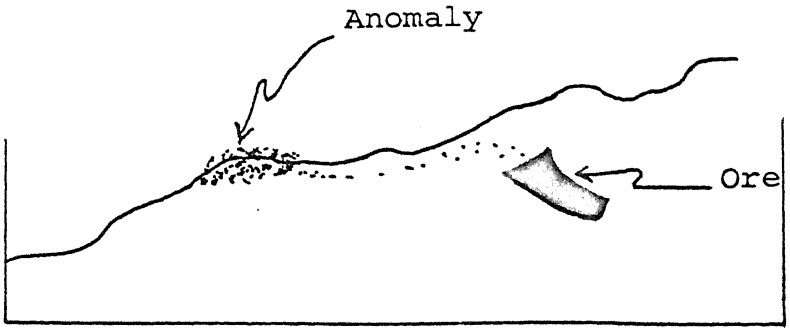
b. Human contamination.

c. Sampling and analytical errors.

If the conclusion, after considering all the points mentioned in this chapter, is that an anomaly is significant, a general procedure for follow-up includes further investigation by some other methods as well as a more detailed check in the anomalous area using geochemical tests.



Superjacent Anomaly



Lateral Anomaly

Figure 9. Superjacent anomaly and lateral anomaly.

APPENDIX B

CHEMICAL RESULTS

Table I

Cold-Extractible Copper Content, Area No. 1

Sample No.	Cold-extractible Copper ppm
76	5
77	7.5
78	7.5
79	0
80	5
81	0
82	0
83	0
84	2.5
85	2.5
86	0
87	2.5
88	5
89	2.5
90	5
91	5
92	15
93	20

Sample No.	Cold-extractible Copper ppm
94	35
95	20
96	5
97	10
98	0
99	2.5
100	0
101	2.5
102	0
104	2.5
105	0
106	0
107	0
108	0
109	0
110	0
111	0
112	0
113	0
114	0
115	0
116	0

Sample No.	Cold-extractible Copper ppm
117	0
118	0
119	0
120	0
121	0
122	0
123	0
124	0
125	0
126	10
127	2.5
128	5

Table II

Cold-Extractible Copper Content, Area No. 2

Sample No.	Cold-extractible Copper ppm
129	0
130	87.5
131	100
132	60
133	50
134	25
135	10
136	0
137	0
138	0
139	0
140	0
141	25
142	35
143	90
144	20
145	45
146	100
147	45

Sample No.	Cold-extractible Copper ppm
148	50
149	35
150	40
151	1275
152	150
153	175
154	140
155	125
156	150
157	100
158	175
159	10
160	0
161	0
162	0
163	0
164	0
165	0
166	0
167	0
168	0

Sample No.	Cold-extractible Copper ppm
169	0
170	0
171	0
172	0
173	65
174	200
175	200
176	525
177	1100
178	500
179	55
180	0
181	0
182	0
183	0
184	0
185	25
186	10
187	60
188	25
189	50

Sample No.	Cold-extractible Copper ppm
169	0
170	0
171	0
172	0
173	65
174	200
175	200
176	525
177	1100
178	500
179	55
180	0
181	0
182	0
183	0
184	0
185	25
186	10
187	60
188	25
189	50

Sample No.	Cold-extractible Copper ppm
190	50
191	40
192	30
193	75
194	100
195	60
196	100
197	15
198	125
199	125
200	0
201	0
202	0
203	0
204	0
205	0
206	125
207	455
208	1200
209	10
210	0
211	> 1800

Table III

Total Copper and Total Zinc Content of
Wash No. 3, Area No. 1

Sample No.	Total Copper ppm	Total Zinc ppm
93	250	200
94	300	200
95	250	200
96	250	200
97	250	350
98	250	200
100	400	350
101	250	200

Table IV

Total Copper Content of Washes No. 5 and 7, Area No. 2

Sample No.	Total Copper ppm
173	1300
174	3500
175	2000
176	6400
177	5000
178	3000
179	2000
193	400
194	500
195	400
196	500
197	400
198	500
206	500
207	4000
208	6000
209	250
210	250

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VITA

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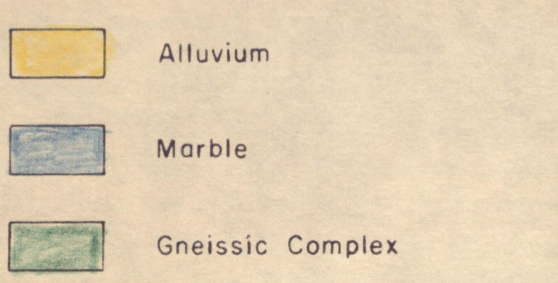
In February 1964 he dually enrolled in the University of Missouri at Rolla for work toward his Master's degree in geology (geochemistry).

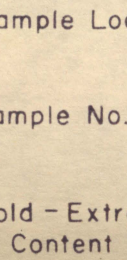
PLATE II

GEOLOGIC MAP OF AREA NO. 1 WITH SAMPLE LOCATION AND COPPER CONTENT

LEGEND

- Alluvium
- Marble
- Gneissic Complex
- Fault Zone
- ● Sample Location
- 94 Sample No.
- 35 Cold – Extractible Copper Content in ppm.
- (2) Wash No.





(Geology after Fernandez, 1965)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BLACK PEAK QUADRANGLE
ARIZONA–CALIFORNIA
15 MINUTE SERIES (TOPOGRAPHIC)

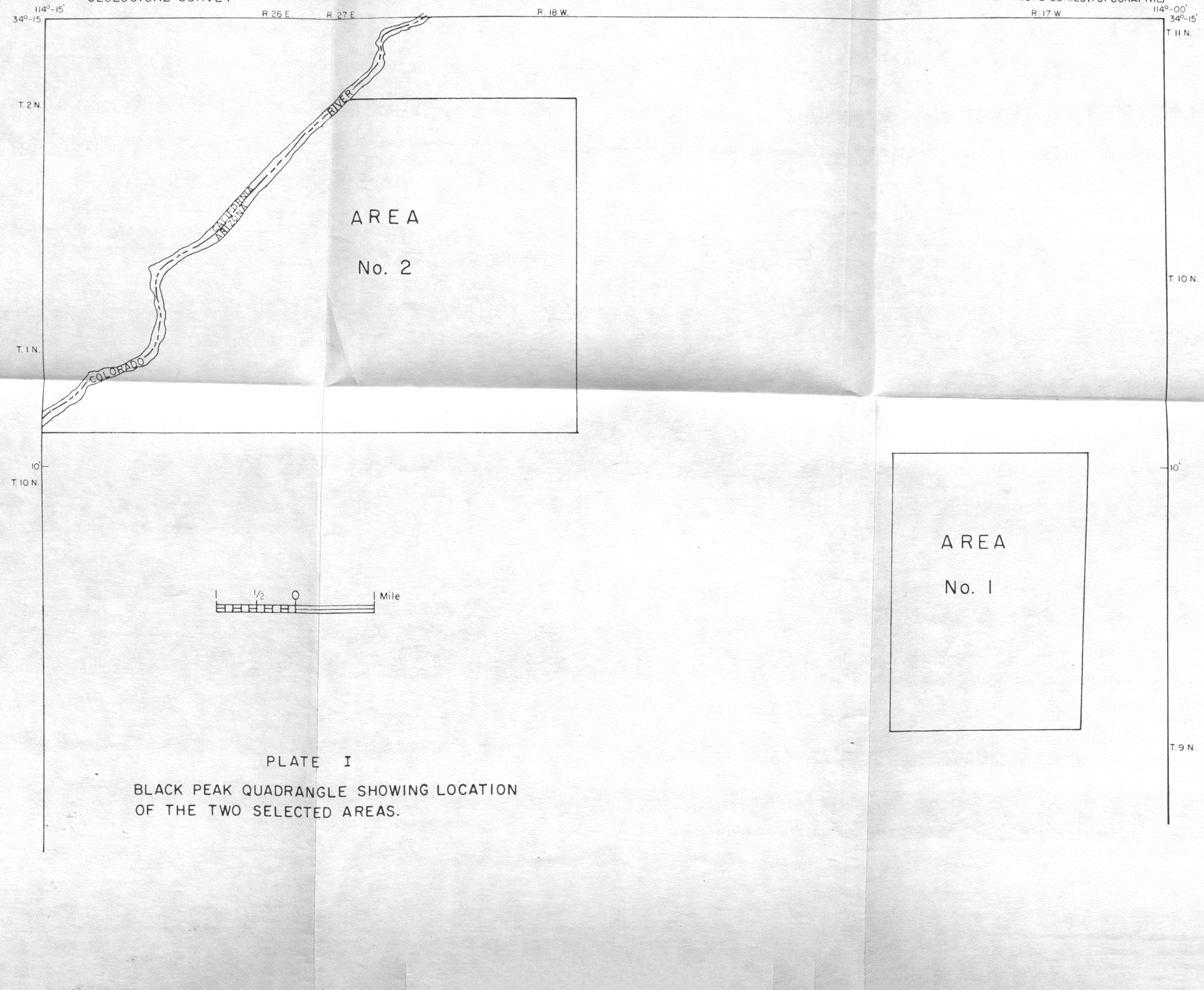


PLATE I

BLACK PEAK QUADRANGLE SHOWING LOCATION
OF THE TWO SELECTED AREAS.

PLATE III

GEOLOGIC MAP OF AREA NO. 2 WITH SAMPLE LOCATION AND COPPER CONTENT

LEGEND

- Alluvium
- Lava Flows
- Tertiary Cretaceous Sediments
- Marble
- Gneissic Complex
- Granite Intrusions
- ● Sample Locations
- 132 Sample No.
- 60 Cold-extractible Copper Content in ppm.
- (3) Wash No.
- Fault

0 ½ Scale in Miles

True North / Magnetic North 15°

COLORADO RIVER
CALIFORNIA
ARIZONA

Sue Mine
Billy Mack Mine
Rio Vista Mine
Gray Eagle Mine
Eagles Nest Mine

(Geology after Zambrano, 1965)